BCI MINERALS LIMITED

MARDIE SALT PROJECT: MARINE TURTLE MONITORING PROGRAM

Prepared by

Pendoley Environmental Pty Ltd

For

BCI MINERALS LIMITED

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1 INTRODUCTION

1.1 Project Background

Mardie Minerals Pty Ltd (Mardie Minerals, a wholly-owned subsidiary of BCI Minerals Limited) is developing the Mardie Project (the Project), a greenfield high-volume salt production venture in the Pilbara region of Western Australia. The Project will produce salt via evaporation of seawater, with a proposed production rate of 3–3.5 million tonnes per annum of concentrated salt, and 50,000 tonnes per annum of Sulphate of Potash (SoP)..

The Project will comprise a series of evaporation and crystalliser ponds encompassing an area of ~10,200 ha, built predominately over existing mud and salt flat habitat. It will also feature a processing plant, a bitterns disposal pipeline and outfall, a trestle jetty and supporting infrastructure to produce and export salt and SoP. Bitterns will be the only marine waste product produced during operations.

The Project received approval under the *Environmental Protection Act 1986* (EP Act) in November 2021 and was classified as a controlled action under the *Environment Protection and Biodiversity Act 1999* (EPBC Act) in January 2022. Construction and operation of the Project is subject to approval conditions prescribed under Ministerial Statement No. 1175 (MS 1175; EP Act) and EPBC2018/8236 (EPBC Act).

The importance of the Project's wider region to marine turtles' survival is recognised under the Commonwealth Government's *Recovery Plan for Marine Turtles* (Department of Environment and Energy 2017). This includes the nearshore islands in the vicinity of the project site which are recognised as habitat critical to the survival of flatback turtle (*Natator depressus*) for nesting, in addition to the waters 60 km around the islands which are used by flatback turtles for internesting (Department of Environment and Energy 2017). Sholl Island is also recognised as habitat critical to the survival of hawksbill turtles (*Eretmochelys imbricata*), including a 20 km zone around the island for internesting. The entire island chain from Mangrove Islands to Cape Preston is recognised as foraging habitat for green (*Chelonia mydas*), hawksbill and flatback turtles.

MS 1175 and EPBC2018/8236 contain approval conditions pertaining to the protection of marine turtles. Studies undertaken by Pendoley Environmental Pty Ltd (PENV) in the austral summers of 2018/19 and 2021/22 identified that marine turtles utilise sandy beach habitat along the mainland coast and offshore islands in the vicinity of the Project for nesting activities (Pendoley Environmental 2019, 2022). Flatback, hawksbill and green turtles were all recorded nesting at offshore islands, and nests or nesting attempts were recorded for flatback and hawksbill turtles on mainland beaches to the east and west of Mardie Creek (Pendoley Environmental 2019, 2022, 2023). Due to this activity, the proponent is required to develop and implement a Marine Turtle Monitoring Program (MTMP) to further describe the nesting population and habitat, and to assess any impacts Project-attributable artificial light emissions may be having on marine turtle behaviour on the nesting beach.

1.2 Ministerial Conditions

MS1175 (published on 24 November 2021) and EPBC2018/8236 (published 12 January 2022) include conditions relating to the protection and conservation of marine turtles during construction and operation of the Project. All conditions relating to marine turtles from these two documents have been reproduced in **Appendix A**, however only MS1175 condition 10-1(2) and 10-4, and EPBC2018/8236 condition 19 (a) are addressed by this document (**Table 1**). Other conditions relate to the implementation and revision of this plan, and other related documents incumbent on Mardie Minerals.

As required under EPBC condition 19 (c) ***Evidence*** *that condition 10-4(2) of the* ***WA Approval*** *is met must be developed with, and reviewed by, a* ***suitably qualified expert*** *in marine turtle ecology and be provided to the* ***Minister*** *for review*. This MTMP for the Mardie Salt Project has been developed by Dr K Pendoley. Her qualifications include a PhD in marine turtle biology/ecology, hosting/attending three of the most recent International Sea Turtle Symposia, publishing in the scientific marine turtle literature in the past three years, serving as a peer reviewer for several scientific journals and is a member of the IUCN Marine Turtle Specialist Group.

Table 1: Approval Conditions addressed by the Marine Turtle Monitoring Program as outlined in the Environmental Protection Authority Ministerial Statement 1175 (Conditions 10-1, 10-4, 10-6) and the *Environment Protection and Biodiversity Conservation Act 1999* EPBC 2018/8236 (Condition 19).

Condition No.	Condition	Section/Survey Reports/Plans
10-1 (2)	The proponent shall implement the proposal to meet the following environmental outcome: (2) no **adverse impact** to marine turtle behaviour on offshore islands as a result of project attributable light	Sections 3.4.1, 3.4.3, 3.4.4 this Plan
10-4	Prior to the commencement of operations the proponent shall submit to the CEO a Marine Turtle Monitoring Program. This plan shall: (1) when implemented, substantiate that the outcome required by condition 10-1(2) is being met; (2) when implemented, determine whether artificial light emissions are influencing nesting and mis-orientation or disorientation of turtles on the offshore islands (including but not limited to Long and Sholl islands), and any areas determined to be significant turtle nesting habitat by surveys required by condition 10-3; (3) specify the details of the methodology of monitoring of the nesting turtle population in the proposal area and offshore islands, including nesting adults and hatchlings, during the species-specific reproductive period, which is to include (but not be limited to): a. identification of the species of turtles nesting on the beaches; b. identification of the abundance and the distribution of adult tracks on the nesting beaches; c. collection of data on the health of the nesting habitat; d. collection of data on hatchling orientation; and e. measurements on the intensity and extent of light sources visible from nesting beaches. (4) include a commitment to annually compare cumulative results against the baseline assessment (Pendoley Environmental 2019, Mardie Salt Project Marine Turtle	(1) This Plan (2) Sections 3.4.1, 3.4.3, 3.4.4 this Plan; 2018/19 and 2021/2022 pre-construction survey Reports; pre-construction and operation Illumination Plans (3) a. Section 3.4.1, 3.4.2 b. Section 3.4.1 c. Section 3.4.2 d. Section 3.4.3 e. Section 3.4.4 (4) Section 4 this Plan (2018/19, 2021/22, 2022/23 baseline assessments)

Condition No.	Condition	Section/Survey Reports/Plans
	Monitoring Program 2018/2019. Rev 0, Report No. RP-59001); (5) include measures to reduce light to offshore islands to be implemented in the event that **adverse impacts** from the proposal are detected, including a decrease in percentage range and usage of nesting sites (from the baseline study (Pendoley Environmental 2019, Mardie Salt Project Marine Turtle Monitoring Program 2018/2019. Rev 0, Report No. RP-59001); and (6) provide criteria for when the Illumination Plan required by condition 9-1 will be revised in response to outcomes of the monitoring required by condition 10-6.	(5) Section 4 and Section 5, this Plan, and Illumination Plan (6) Section 4 this Plan
10-6	The proponent shall continue to implement the Marine Turtle Monitoring Program until the CEO has confirmed by notice in writing, on advice from DBCA and DWER, that the outcomes of condition 10-1(2) has been, and will continue to be met	Section 5 this Plan
19	To minimise impacts to marine turtles, the approval holder must: a. comply with condition 10 of the **WA Approval.**	This Plan

1.3 Program Aim

This MTMP aims to monitor the nesting population of marine turtles in the vicinity of the Project during the species-specific reproductive periods of flatback, hawksbill and green turtles, as required by MS1175 (**Table 1**). It also aims to detect adverse impacts to adult and hatchling marine turtles arising from Project-attributable artificial light emissions, which have the potential to cause the mis-orientation and/or disorientation of marine turtles.

Program methodology has been developed to address the following objectives of MS1175 condition 10-4(3):

(a) identification of the species of turtles nesting on the beaches;

(b) identification of the abundance and the distribution of adult tracks on the nesting beaches;

(c) collection of data on the health of the nesting habitat;

(d) collection of data on hatchling orientation; and

(e) measurements on the intensity and extent of light sources visible from nesting beaches.

2 BACKGROUND

2.1 Marine Turtle Nesting Activity in the Mardie Region

The Project will be constructed on a greenfield site at Mardie, Western Australia, approximately 100 km southwest of Karratha. There are 11 islands offshore in the immediate vicinity of the Project, 10 of which have shown evidence of turtle nesting activity (green, flatback and hawksbill turtles) in pre-construction surveys (**Figure 1**; Pendoley Environmental 2019, 2022). Solitary Island was the only island where turtle activity was not recorded (Pendoley Environmental 2022). Flatback and hawksbill turtles also nest on mainland beaches, although at a much lower density compared to islands (Mardie Creek East and Mardie Creek West, **Figure 1**; Pendoley Environmental 2019, 2022, 2023).

The islands predominantly occur in an island chain oriented north-south off the coast of Mardie and share similar morphologic features (**Figure 1**). They typically feature a dynamic sand spit on the southern or south-eastern extent, a moderately wide and sloped intertidal zone, a wide supratidal zone, and vegetated dunes adjacent to sandy nesting habitat (**Figure 2**).

Mainland beaches, including those to the east and west of Mardie Creek are long and low energy beaches with broad and shallow intertidal zones, narrow supratidal zones, and permanently vegetated dunes set back from the beach (**Figure 2**). Sections of the mainland coast are occupied by extensive mangrove forests, such as stretches to the west of Mardie Creek and at creek mouths. Beach sediment is typically dark brown or red, and ranges in composition from stones and gravel to medium-coarse sand.

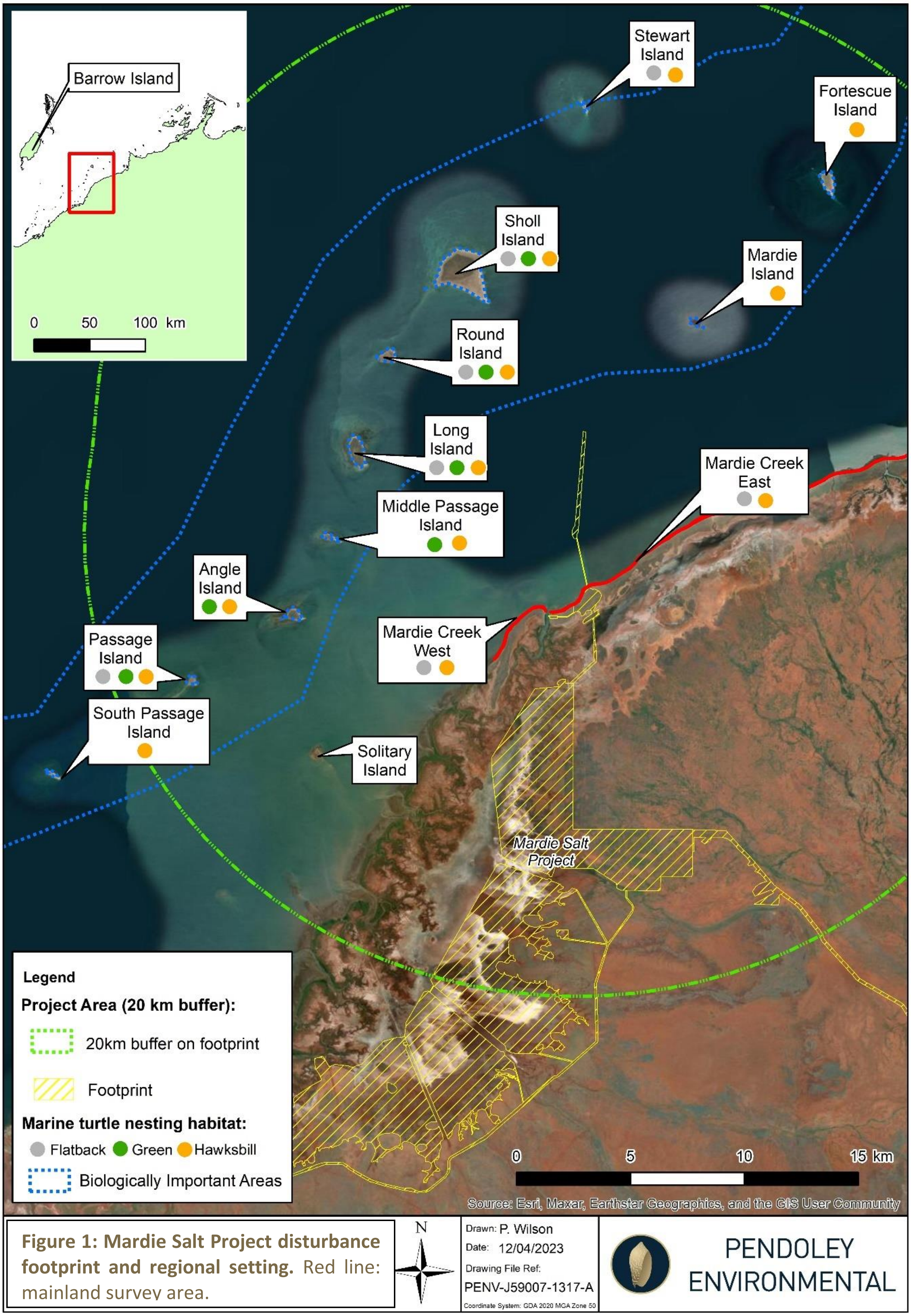

Figure 1: Mardie Salt Project disturbance footprint and regional setting. Red line: mainland survey area.

Figure 2: Example of nesting habitat on offshore islands (a. Angle Island) and on the mainland (b. Mardie Creek East).

2.2 Summary of baseline surveys

Three systematic marine turtle monitoring programs have been undertaken for the Project to develop a baseline dataset of marine turtle nesting and hatching activities in the Mardie region. These surveys were undertaken by Pendoley Environmental in the summers of 2018/19, 2021/22 and 2022/23 (Pendoley Environmental 2019, 2022, 2023). Survey effort from these three surveys has been summarised in **Table 2** and **Table 3**.

An additional short-term survey was conducted prior to these surveys in 2017/18 (Pendoley Environmental 2018) (**Table 2**). This survey was undertaken to determine if marine turtles were nesting along the mainland in the Project area as part of a feasibility study. A one-day survey was conducted in December 2017 which identified flatback turtle nesting activity to the west of Mardie Creek. A follow-up survey occurred on 13 January 2018. This survey identified that both flatback and hawksbill turtles nest along the mainland coast (**Table 2**).

To quantify nesting and hatching activity, the 2018/19 monitoring program targeted the peak of the flatback and green turtle nesting season in December 2018 and the peak of the flatback and green turtle hatching season in February 2019 (**Table 2**). The surveys were undertaken daily via helicopter and prioritised Sholl Island, Long Island and mainland beaches. Work scopes included recording turtle tracks, marking and excavating turtle nests, and recording hatchling orientation metrics. Artificial light monitoring was also undertaken at these locations. Round, Middle Passage and Angle islands were visited opportunistically to provide a snapshot of nesting activity, including nesting species.

Following identification of hawksbill turtles nesting on the mainland and on islands in the vicinity of the Project, the 2021/22 marine turtle monitoring program was extended to include a survey targeting the peak of hawksbill nesting, which occurs in October in the Pilbara region (**Table 2**). The surveys were primarily conducted via liveaboard vessel, and this allowed time for Round, Middle Passage, Angle and Passage islands to also be included in the routine monitoring effort. However, access to the mainland via vessel was limited to short windows of time on a high spring tide so survey effort at mainland locations was reduced. Opportunistic surveys were conducted on Stewart, Fortescue, Mardie, South Passage and Solitary islands.

Further monitoring was conducted in 2022/23 to gather additional baseline data on nesting density and hatchling orientation on mainland beaches as previous surveys focused primarily on offshore islands (due to the greater turtle nesting on the islands and difficulties in accessing the mainland). Consequently there was no targeted mainland survey data during the peak of the hawksbill nesting season (October). Daily surveys were conducted via helicopter and/or by foot over approximately 23 km of coastline (red line: **Figure 1**) to document nesting activity, mark and excavate nests, monitor hatching success and orientation and conduct light monitoring.

Table 2: Marine Turtle Monitoring undertaken for the Mardie Salt Project prior to construction.

Monitoring Program	Survey dates	Locations monitored	Work Scopes Completed
2017/18	5 December 2017 13 January 2018	**Opportunistic** Mardie Creek East and West	• Snapshot Survey
2018/19	**Field Survey 1:** 1 – 15 December 2018 **Field Survey 2:** 30 January – 12 February 2019	**Routine:** Sholl and Long islands, Mardie Creek East and West **Opportunistic:** Round, Middle Passage and Angle islands	• Track Census • Incubation Success • Hatchling Orientation • Artificial Light Monitoring
2021/22	**Field Survey 1:** 20 October – 4 November 2021 **Field Survey 2:** 3 – 17 December 2021 **Field Survey 3:** 4 – 14 February 2022	**Routine:** Sholl, Round, Long, Middle Passage, Angle and Passage islands. **Opportunistic:** Stewart, Fortescue, Mardie, South Passage and Solitary islands, Mardie Creek East and West	• Track Census • Incubation Success • Hatchling Orientation • Artificial Light Monitoring
2022/2023	**Field Survey 1:** 17 - 31 October 2022 **Field Survey 2:** 3 - 17 December 2022 **Field Survey 3:** 13 – 27 February 2023	**Mainland:** Mardie Creek East to Fortescue River and West to mangroves	• Track Census • Incubation Success • Hatchling Orientation • Artificial Light Monitoring

Table 3: Survey duration within each sampling period per season prior to construction of the Mardie Project (excluding "line in" day). Note that not all locations were sampled every day during each survey period.

Location	Survey duration 2018/19			Survey Duration 2021/22			Survey Duration 2022/23		
	Oct	Dec	Feb	Oct	Dec	Feb	Oct	Dec	Feb
Sholl Island		13	12	14	12	5	-	-	-
Round Island		1*	-	13	11	5	-	-	-
Long Island		13	12	13	12	5	-	-	-
Middle Passage Island		1*	-	13	12	5	-	-	-
Angle Island		1*	-	12	11	5	-	-	-
Passage Island		-	-	12	9	5	-	-	-
South Passage Island		-	-	1*	-	-	-	-	-
Stewart Island		-	-	1*	1*	-	-	-	-
Fortescue Island		-	-	1*	2*	-	-	-	-
Mardie Island		-	-	13	9	1*	-	-	-
Solitary Island		-	-	1*	-	-	-	-	-
Mardie Creek East		13	12	10#	1*	2	14	14	14
Mardie Creek West		13	12	10#	1*	2	14	14	14

*one-off snapshot surveys were conducted at these locations

These locations were only visited twice during the survey.

2.2.1 Nesting Habitat: Track Census

2.2.1.1 Summary of results from baseline surveys

The spatial distribution of all nests, and the nesting species, recorded during all monitoring programs are provided in maps in **Appendix B**. Nesting distribution indicates that nesting effort was a function of available nesting habitat, with larger islands with long, sandy stretches of beach receiving the highest number of turtles, which were predominantly flatback turtles (i.e., Sholl and Long islands). Flatback and hawksbill turtles were more equally represented on the smaller islands, such as Round, Middle Passage, and Passage islands.

The track census results of 2018/19 and 2021/22 for the equivalent December survey show that nesting activity was similar for both periods on Sholl and Long islands (**Table 4**). Data collected to date highlights that Sholl and Long islands are the most significant rookeries in the Project area (**Figure 3**), recording 76% of all turtle tracks in 2021/22 when combined. These two islands were most frequently used by flatback turtles, followed by hawksbill turtles, with minimal contribution by green turtles. The exception was in October 2021 when Sholl Island was more frequently used by hawksbill turtles (**Table 4**).

Green turtles were recorded nesting on the islands only, mainly on Long, Sholl and Passage Islands and nesting success (proportion of tracks that resulted in a successful nesting attempt) was usually low (**Table 4**). Hawksbill turtles were recorded on all the islands except Solitary, particularly on Sholl, Round, Long and Middle Passage. They were also recorded nesting on the mainland at both Mardie

Creek East and Mardie Creek West (**Table 4**). Flatback turtles were not as widely spread as hawksbill turtles (nesting activity was not recorded on four of the islands, **Figure 1**) but they were often the most abundant species at each location, especially during the December surveys (**Table 4**). Hawksbill turtles were usually more abundant in October, although some of the islands recorded higher numbers in December 2021 compared to October 2021 (**Table 4**).

Marine turtle nesting on the mainland was minimal during all monitoring periods relative to the islands. Only flatback and hawksbill activity was detected on the mainland (i.e., no green turtle activity) (**Table 4**). As mentioned above, a third survey was conducted in 2022/23 that targeted mainland habitats during which a total of 8 flatback tracks were recorded in December. Hawksbill turtles were recorded nesting on the mainland in December 2018 (Pendoley Environmental 2019) and in October 2022 (Pendoley Environmental 2023). No hawksbill nesting activity was recorded on the mainland in the 2021/22 survey (Pendoley Environmental 2022).

There was a low amount of turtle nesting activity recorded in February surveys (**Table 4**).

Table 4. The total number of tracks (nests) and nesting success recorded at each routine monitoring location during the baseline monitoring. FB: Flatback turtle, HK: Hawksbill turtle, G: Green turtle.

Location	Species	2018-2019		2021-2022			2022-2023			Total (nesting success %)
		Dec	Feb	Oct	Dec	Feb	Oct	Dec	Feb	
Sholl Island	*FB*	89 (39)	30 (11)	8 (5)	83 (34)	10 (1)				220 (40.9)
	G	6 (1)	0	0	7 (1)	1 (0)				14 (14.3)
	HK	4 (1)	2 (2)	18 (8)	9 (4)	0				33 (45.4)
	Total	**99 (41)**	**32 (13)**	**26 (13)**	**99 (39)**	**11 (1)**				**267 (40.1)**
Round Island	*FB*			1 (0)	7 (2)	0				8 (25)
	G			0	1 (0)	0				1 (0)
	HK			18 (10)	16 (6)	0				34 (47)
	Total			**19 (10)**	**24 (8)**	**0**				**43 (41.9)**
Long Island	*FB*	135 (41)	21 (14)	21 (13)	64 (23)	0				241 (37.7)
	G	9 (2)	0	2 (2)	6 (1)	0				17 (29.4)
	HK	8 (3)	1 (0)	4 (0)	28 (14)	0				41 (41.5)
	Total	**152 (46)**	**22 (14)**	**27 (15)**	**98 (38)**	**0**				**299 (37.8)**
Middle Passage Island	*FB*			3 (2)	10 (4)	0				13 (46.1)
	G			0	0	0				0 (0)
	HK			11 (7)	5 (1)	0				16 (50)
	Total			**14 (9)**	**15 (5)**	**0**				**29 (48.3)**
Angle Island	*FB*			0	5 (4)	0				5 (80)
	G			0	0	0				0 (0)
	HK			5 (1)	2 (1)	0				7 (28.6)
	Total			**5 (1)**	**7 (5)**	**0**				**12 (50)**
Passage Island	*FB*			0	8 (5)	2 (1)				10 (60)
	G			2 (1)	3 (1)	0				5 (40)
	HK			4 (3)	4 (2)	0				8 (62.5)
	Total			**6 (4)**	**15 (8)**	**2 (1)**				**23 (56.5)**
Mardie Island	*FB*			0	0					0 (0)
	G			0	0					0 (0)
	HK			5 (1)	2 (0)					7 (14.3)
	Total			**5 (1)**	**2 (0)**					**7 (14.3)**
Mardie Creek East	*FB*	2 (0)	5 (1)	2 (1)		7 (2)	5 (2)	8 (3)	0	28 (32.1)
	G	0	0	0		0	0	0	0	0 (0)
	HK	1 (1)	0	0		0	8 (3)	0	0	9 (44.4)
	Total	**3 (1)**	**5 (1)**	**2 (1)**		**7 (2)**	**13 (5)**	**8 (3)**	**0**	**38 (34.2)**
Mardie Creek West	*FB*	2 (0)	1 (1)	1 (1)		0 (0)	0	0	0	4 (50)
	G	0	0	0		0	0	0	0	0 (0)
	HK	1 (0)	0	0		0	0	0	0	1 (0)
	Total	**3 (0)**	**1 (1)**	**1 (1)**		**0 (0)**	**0**	**0**	**0**	**5 (40)**
All sites	**Total dataset**	**257 (88)**	**60 (29)**	**105 (55)**	**260 (103)**	**20 (4)**	**13 (5)**	**8 (3)**	**0**	**722 (39.7)**

- Unknown species were excluded from this summary
- Only routine monitoring data has been included in this table (shaded cells **Table 3**).

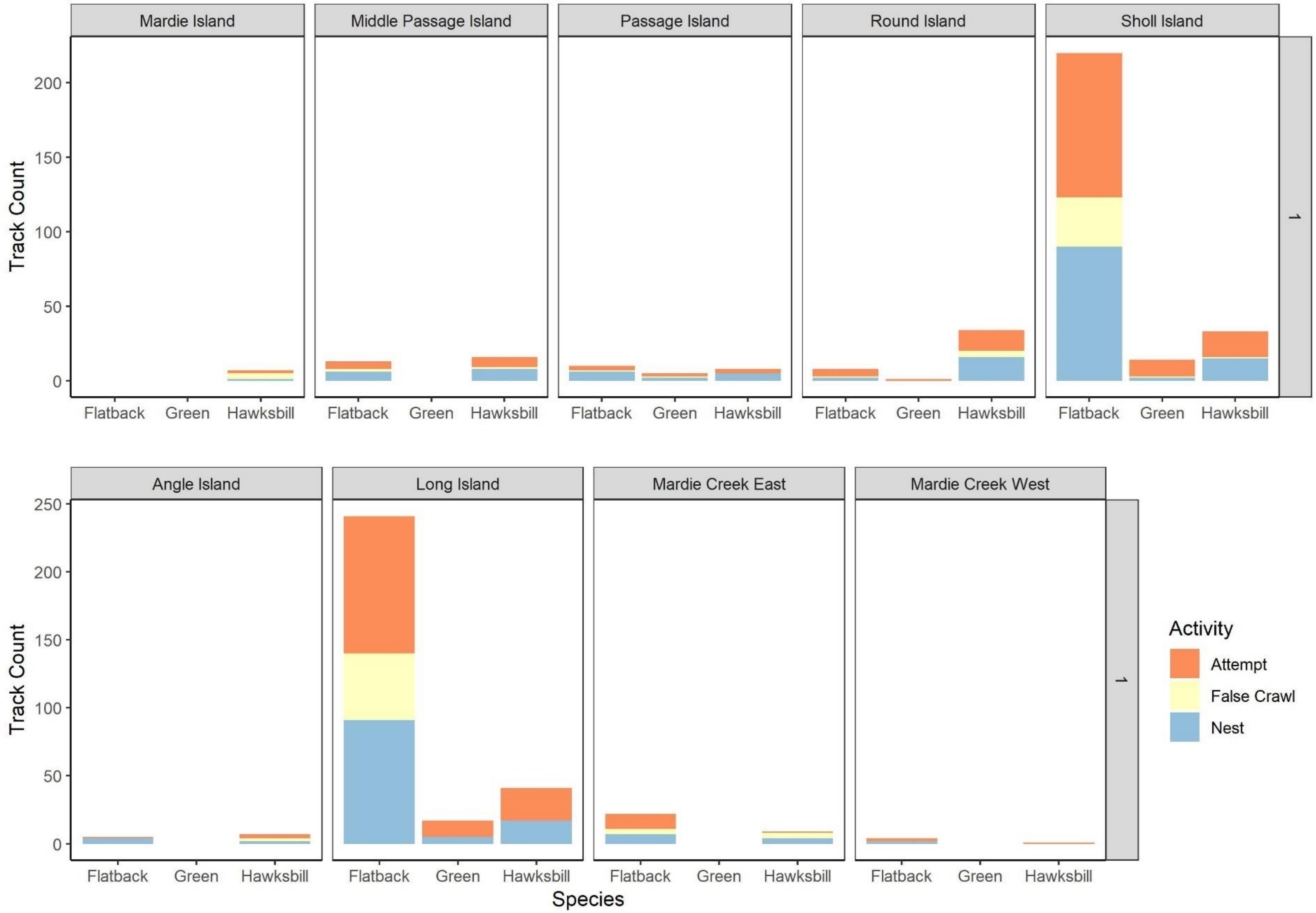

Figure 3. Summary of track census data from routine monitoring locations summarised in Table 4.

2.2.2 Nesting Habitat Health Assessment

The mean clutch size of flatback nests across all routine monitoring islands from the 2018/19 and 2021/22 monitoring periods was 50 ± 11 eggs (*n* = 34). The mean hatch success for flatbacks was 56.3% and the mean emergence success was 48.2%. A summary of incubation success metrics for each survey and location are provided in **Table 5**.

The mean clutch size of hawksbill nests from the 2018/19 and 2021/22 monitoring periods on the islands was 112 ± 19 eggs (*n* = 7). Of all excavated clutches, three were inundated during the incubation period and resulted in hatch and emergence success rates of <2%. The mean hatch success for hawksbill nests that weren't inundated was 81.8%, and the mean emergence success was 79.4%.

The 2018/19 and 2021/22 monitoring programs recorded lost clutches where nests were marked on island spits, or where notable beach erosion had occurred, such as the southern edge of each of the islands in 2021/22. Two marked nests were lost in 2018/19 and eleven were lost in 2021/22. This indicates island morphology is highly dynamic and nests are naturally vulnerable to inundation or being washed away during periods of high spring tides coupled with bad weather.

A total of two flatback nests were excavated on the mainland in 2021/22 and they had the highest hatch and emergence success rates out of all locations (91.8%; **Table 5**). Five more flatback turtle nests were excavated in 2022/23 and although clutch size was similar (*n* = 56) hatching success was much lower (55.6%). The mean clutch size of hawksbill turtle nests on the mainland was 98 eggs and hatching success was approximately 60% (**Table 5**).

Table 5: Incubation success metrics for clutches excavated in 2018/19, 2021/22 and 2022/23 monitoring programs. Shaded cells indicate no data available. *Includes data from inundated nests. FB: Flatback turtle, HK: Hawksbill turtle.

Location	Species	2018/19				2021/22				2022/23			
		n	Mean Clutch Size	Mean Hatch Success	Mean Emergence Success	*n*	Mean Clutch Size	Mean Hatch Success	Mean Emergence Success	*n*	Mean Clutch Size	Mean Hatch Success	Mean Emergence Success
Sholl	FB	10	55	46.6%	38.5%	3	51	25.8%	15.9%				
	HK	1	123	79.0%	70.0%	2	96	86.9%	86.5%				
Round	FB												
	HK					3*	108	25.4%	25.4%				
Long	FB	10	50	52.3%	44.9%	6	50	79.2%	71.3%				
	HK												
Middle Passage	FB					4	42	66.8%	54.7%				
	HK					1*	145	0%	0%				
Passage	FB					1	46	34.8%	21.7%				
	HK												
Islands Total	**FB**	**20**	**53**	**49.5%**	**41.7%**	**14**	**48**	**64.9%**	**56.2%**				
	HK	**1**	**123**	**79.0%**	**70.0%**	**6**	**110**	**41.7%**	**41.5%**				
Mainland	**FB**					2	59	91.8	91.8	5	56	55.6%	55.2%
Mainland	**HK**									2	98	59.9%	57.5%

2.2.3 Hatchling Orientation

A total of 90 hatchling fans were recorded during baseline monitoring (**Figure 4**). Most (87 out of 90) were recorded on the islands (mainly on Long and Sholl islands) and three have been observed on the mainland. All nest fan data collected on Sholl and Long islands are displayed in **Figure 4**. Nest fan data collected on Round, Middle Passage and Passage islands and on the mainland are not presented due to the low number of fans (Pendoley Environmental 2022, 2023). Spread and offset angles from nest fans at Long and Sholl islands will be used to describe a natural range of orientation behaviours for comparison in future monitoring. Further details are provided in **Section 3.4.3**.

The hatchling orientation data indicates that marine turtle hatchlings are currently successfully oriented seaward, regardless of their orientation on the beach (e.g. Sholl Island north and south) and despite the visibility of light sources (see **Section 2.2.4**). It was common however for hatchling fans occurring on sand spits to have larger spread angles, due to the position of the ocean being on either side of the nest and therefore hatchlings moving in either direction. It was also common to observe circuitous hatchling tracks in these areas due to competing natural cues, and nest fan metrics could not always be determined. Collection of data on sand spits is therefore not recommended for future monitoring.

Table 6: Summary of nest fan data collected during baseline surveys.

Statistic		Sholl Island	Round Island	Long Island	Middle Passage Island	Passage Island	Mainland
2018/19	***n***	**24**		**30**			
Spread Angle (°)	Mean	59.5		51.7			
	St. Dev	31.8		20			
Offset Angle (°)	Mean	8.7		10.1			
	St. Dev	11.7		9.3			
2021/22	***n***	**14**	**2**	**11**	**4**	**2**	
Spread Angle (°)	Mean	61.4	35.5	71.8	80	41	
	St. Dev	15.4	16.3	29.2	59.9	29.7	
Offset Angle (°)	Mean	9.0	7.8	10.5	15.0	16.5	
	St. Dev	7.1	8.1	8.5	27.4	10.6	
2022/23	***n***						**3**
Spread Angle (°)	Mean						36.7
	St. Dev						5.8
Offset Angle (°)	Mean						8
	St. Dev						2.6
Total number		**38**	**2**	**41**	**4**	**2**	**3**

Figure 4: Hatchling orientation data collected at Sholl and Long islands in 2018/19 and 2021/22.

2.2.4 Artificial Light Monitoring

Light monitoring data has been collected on offshore islands and on the mainland (**Figure 5**). In 2018/19 measured whole-of-sky brightness ranged from 23.87 (Mardie Creek East) to 22.55 Vmag/arcsec^2 (Mardie Creek West) on the mainland and islands which is categorised as ideal natural dark night skies (see categories in **Section 3.4.4**) (**Table 7**). Whole-of-sky brightness increased at Long and Sholl islands in 2021/22 (22.84 – 21.19 Vmag/arcsec^2 at Long island, 23.05 – 21.16 Vmag/arcsec^2 Sholl Island) and they were further categorised as having a rural night sky. In 2022/23, all monitoring sites were classified as having a semi-rural to rural night sky conditions. The brightest WOS sky brightness value was captured at the Fortescue River (20.89 Vmag/arcsec^2) monitoring location, which was classified as semi-rural (**Figure 6**). Skies were darkest at locations in 2018/19 and brightness increased in subsequent years at all sites (**Figure 6**).

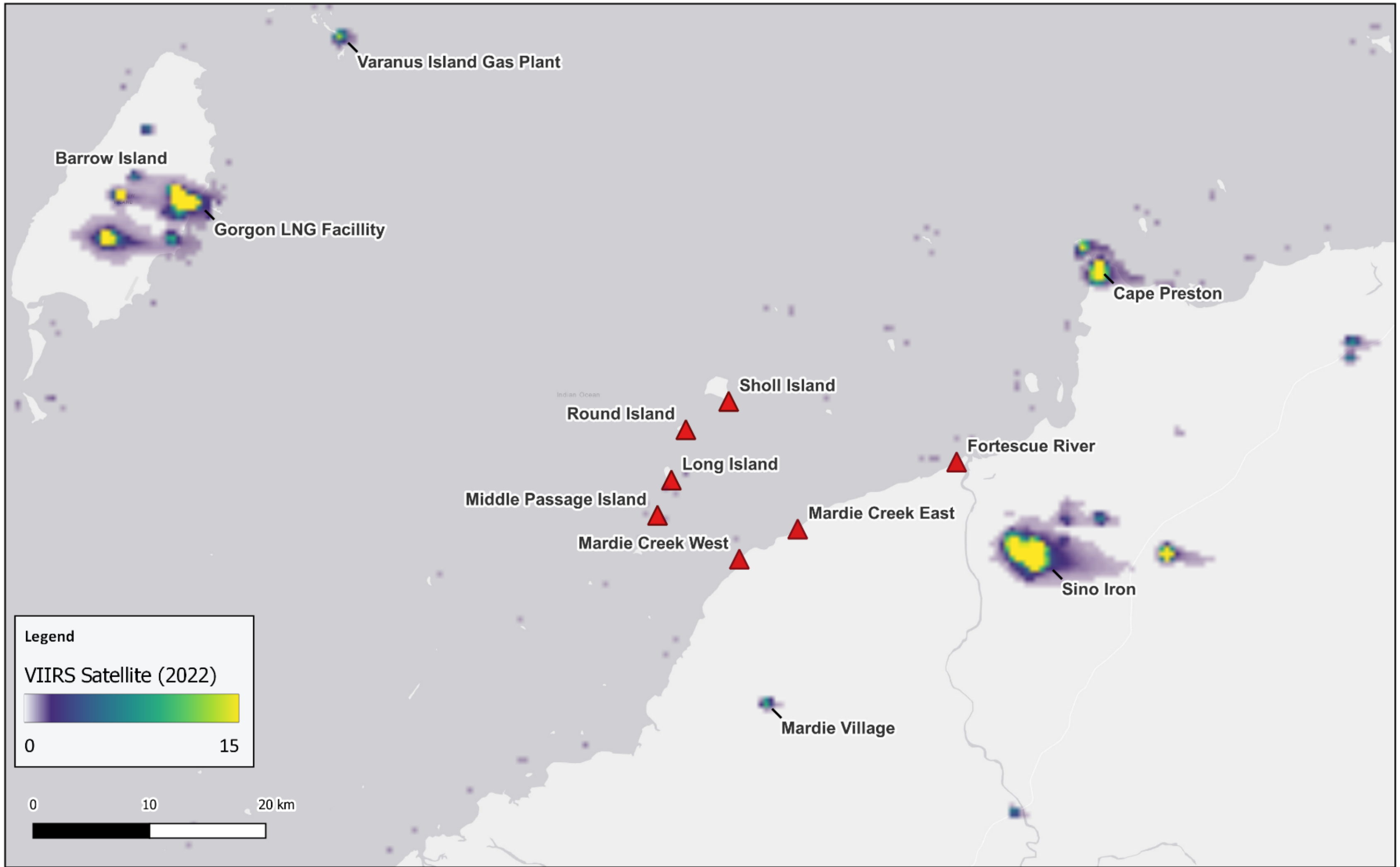

Figure 5: Artificial light monitoring locations and light sources in the Mardie Project Area. Triangles indicate light monitoring locations during baseline surveys. Source: VIIRS 2022 Satellite Data (www.lightpollutionmap.info).

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Table 7: Average magnitude for whole-of-sky, zenith and horizon captured at each monitored beach section during baseline surveys.

Beach Section	Year	Clear Sky (Vmag/arcsec^2)		
		Whole-of- Sky	Zenith	Horizon
Mardie Creek East	2018/19	23.87	25.5	-
	2022/23	21.24	21.45	21.08
Mardie Creek West	2018/19	22.55	24.55	-
	2022/23	21.34	21.43	21.25
Long Island	2018/19	22.84	25.16	-
	2021/22	21.19	21.44	21.08
Sholl Island	2018/19	23.05	25.51	-
	2021/22	21.16	21.43	21.03
Fortescue	2022/23	20.89	21.49	20.65

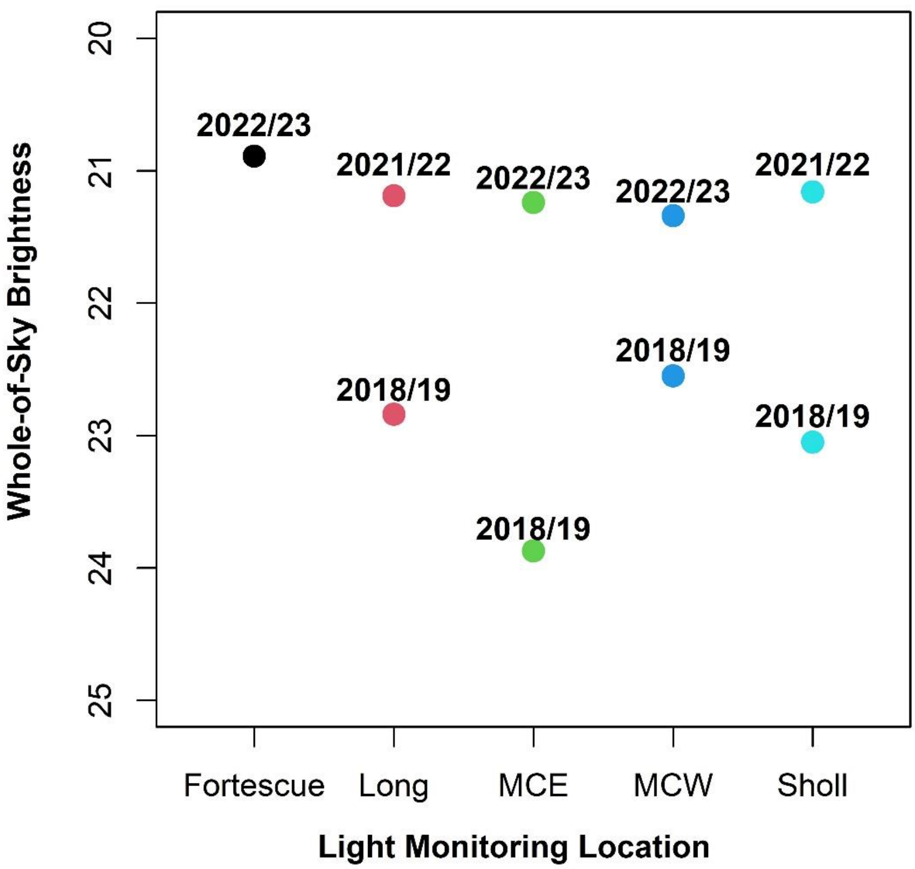

Figure 6. Whole-of-Sky brightness (Vmag/arcsec^2) measured at each monitoring location each season

2.2.4.1 Visible light sources:

Offshore Islands

Artificial light data indicated the night skies overhead the islands (zenith) were almost entirely free of artificial light and were representative of ideal natural dark night sky in 2018/19. In 2021/22 sky brightness increase and they were classified as having a rural night sky. Mardie Village was recognised as a new source of light visible in 2021/22 that was not present in 2018/19. Light sources visible on the horizon from the Sholl and Long Island spits, current as of February 2022 include:

- Cape Preston
- Sino Iron iron ore mine
- Mardie Minerals accommodation camp
- Rio Tinto MESA A iron ore mine
- Barrow Island
- Varanus Island

Mainland

Artificial light data indicated that whole-of-night-skies were representative of rural to semi-rural levels in 2022/23. Previously in 2018/19, these locations were classified as having ideal natural dark skies. Light sources visible on the mainland, current as of February 2023 include:

- Cape Preston
- Sino Iron iron ore mine
- Mardie Minerals accommodation camp
- Barrow Island

3 Monitoring Program

The MTMP detailed in the following sections has been designed to monitor and detect any adverse impact to marine turtle behaviour as a result of the Project, particularly attributable to artificial light (MS Condition 10-1 (2) and 10-4 (5)). Monitoring locations were determined based on the results of baseline surveys, having adequate baseline data to measure any change, their regional significance, and their proximity to the project footprint.

This monitoring program includes (but not is limited to) as outlined in MS Condition 10-4 (3):

- Identification of the species of turtles nesting on the beaches;
- Identification of the abundance and the distribution of adult tracks on the nesting beaches;
- Collection of data on the health of the nesting habitat (incubation success);
- Collection of data on hatchling orientation; and
- Measurements on the intensity, direction, and extent of light sources visible from nesting beaches.

3.1 Survey Locations

This monitoring program will routinely monitor mainland beaches, as well as Long and Sholl Islands which are recognised as critical habitat for flatback and hawksbill turtles (Department of Environment and Energy 2017).

The baseline dataset highlighted the importance of Long and Sholl Islands as significant nesting habitats for marine turtles, particularly for flatback turtles. In December 2018, the baseline surveys recorded more than 10 flatback turtle tracks per night on Long Island (**Table 9**). These results are consistent with Fossette et al. (2021) that recorded high abundances (10 – 49 tracks per night) of marine turtle activity on this island. Flatback turtle nesting activity was slightly lower at Sholl Island (~6 tracks per night in the December 2018 and December 2021 surveys) (**Table 9**). Both of these islands were also nesting sites for green and hawksbill turtles and Sholl Island has been identified as an important nesting site for hawksbill turtles from the Western Australia genetic stock (Department of Environment and Energy 2017). Additionally, this entire island chain and surrounding waters has been identified as Biologically Important Areas for all three marine turtle species (Department of Environment and Energy 2017). Given their regional significance, and that baseline surveys recorded the highest density of nesting activity at these two sites, routine monitoring will occur at Long and Sholl Island. Adequate baseline data (track census and hatchling orientation data) was obtained at Long and Sholl Islands to allow for comparisons during construction and operation. The mainland will also be monitored due to its immediate proximity to the Project area and the potential for disturbance to marine turtle behaviour from Project lighting.

Monitoring may also involve opportunistic surveys of other islands in the immediate area (Round, Middle Passage, Angle, Passage, South Passage, Mardie, Stewart and Fortescue Islands). The need to continually monitor routine and opportunistic monitoring locations will be reassessed after 5 years of implementing this program.

Monitoring will occur along transects identified in **Appendix B**. Islands will be accessed by boat or by helicopter. Mainland sites will be accessed by road or by helicopter. Mainland beaches include those beaches to the east and west of Mardie Creek. The beach habitat at least 3 km east and 2.5 km west of the loadout jetty will be monitored and will take place at the same time as the offshore island surveys. If the mainland is accessed by road (as opposed to helicopter), Mardie Creek West may not be surveyed due to limitations with access (i.e. road access to Mardie Creek East only and cannot get across Mardie Creek to access western side). Alternative methods such as remote drone track census will be considered for areas that are access-limited.

3.2 Survey schedule

Annual monitoring will commence in the 2023/2024 marine turtle nesting season and will consist of three field surveys each turtle nesting season, including:

- **Field Survey 1 (FS1):** A 14-day survey targeted at the October peak of the hawksbill turtle nesting season.
- **Field Survey 2 (FS2):** A 14-day survey targeted at the December peak of the green and flatback turtle nesting season, and the peak of the hawksbill hatching season.
- **Field Survey 3 (FS3):** A 14-day survey targeted at the February peak of the green and flatback hatching season.

The 14-day internesting period is recommended by the Department of Biodiversity, Conservation and Attractions (DBCA) because this is the mean number of days between nesting events for individual females. By collecting data across one whole internesting cycle at the peak of the nesting season it is possible to estimate the number of individual females nesting at that time. As the arrival and departure of females at the rookeries is staggered, monitoring at the peak of the nesting season is estimated to capture ~80% of the females nesting in that season. This approach provides a confident estimate on the size of the nesting population at each survey site and can be compared with other rookeries for regional comparisons.

The February survey will also be 14 days long to allow enough time to excavate marked and opportunistic nests, and to collect a suitable sample size of hatchling orientation data. If sufficient data can be obtained in a shorter timeframe, then the survey duration of FS3 may be reassessed and potentially scaled down.

3.3 Standard Methods, Licences and Animals Ethics

The survey methods detailed in the following sections are consistent with those used by turtle biologists and ecologists in DBCA North West Shelf Flatback Turtle Conservation Program, including survey timing, duration and techniques. The methods are also consistent with the recommendations of the National Light Pollution Guidelines (Department of Environment and Energy 2020). Specifically, adult nesting and habitat health assessment and hatchling orientation surveys will take place over 14 days for each program.

The programs will be scalable depending on seasonal survey results and will be discussed with the Department of Water and Environment Regulation Environment Protection Authority Services prior to making modifications to the scope of the program.

All work scopes will be conducted under a Section 40 Authorisation to take or disturb threatened species, issued by DBCA under the *Biodiversity Conservation Act 2016*. Should helicopters be used to access any of the islands of the Great Sandy Island Nature Reserve (including the survey islands listed in this report), a Regulation 4 Lawful Authority Notice to conduct Activity on CALM Land will be required.

Where applicable, the monitoring methods will be submitted for Animal Ethics approval prior to commencement of the monitoring season. Under the *Animal Welfare Act 2002* (AW Act), activities involving the use of animals for scientific purposes must be conducted in accordance with a licence to use animals for scientific purposes (Scientific Licence) issued by the Department of Primary Industries and Regional Development (DPIRD) and obtain ethical approval from an Animal Ethics Committee (AEC). From 31 July 2022 onwards, all projects that interact with wildlife, including those conducted by environmental consultancies, must be reviewed and approved by an AEC.

3.4 Work Scopes

An overview of the work scopes proposed for the monitoring program is provided in **Table 8** with methodology detailed in the following sections. While every effort will be made to complete each work scope, logistical, human health and safety limitations will ultimately dictate what can be achieved in each field survey.

Table 8: Proposed work scopes to be conducted at each location during each field survey (FS).

Location	Track Census			Incubation Success[1]			Hatchling Orientation			Light Monitoring		
	FS1	FS2	FS3	FS1	FS2	FS3	FS1	FS2	FS3	FS1	FS2	FS3
Routinely surveyed												
Sholl Island	X	X	X	X	X	X	X	X	X		X	X
Long Island	X	X	X	X	X	X	X	X	X		X	X
Mardie Creek East	X	X	X	X	X	X		X	X		X	X
Mardie Creek West[1]	X	X	X	X	X	X		X	X		X	X
Opportunistically surveyed												
Round Island	X	X	X					X	X			
Middle Passage Island	X	X	X					X	X			
Angle Island	X	X	X					X	X			
Passage Island[1]	X	X	X									
Mardie Island	X	X	X					X	X			
South Passage Island	X	X	X					X	X			
Stewart Island	X	X	X					X	X			
Fortescue Island	X	X	X					X	X			

Notes:

1. Work scopes subject to site access.
2. Hatchling orientation will not be undertaken at Passage Island as all the nesting habitat occurs on or adjacent to the spit (Section 3.4.3).

3.4.1 Nesting Habitat: Track Census

This work scope satisfies requirements of MS1175 conditions 10-1 (2), 10-4 (3) (a) and (b) and 10-

This work scope quantifies nesting effort, i.e., the number and species of turtles that nest at each location over the nesting season and nesting distribution, for the three marine turtle species that nest in the region. In particular, the aim of the track census is to:

- identify the species of turtles nesting on the beaches, and
- identify the abundance and distribution of adult tracks on the nesting beaches.

A track census will be undertaken as one of the following:

- Routine monitoring which will occur on Long and Sholl islands and the mainland where sites are visited daily to identify overnight nesting activity. All visible tracks are marked during a 'line-in' day (i.e., first day of each survey) prior to the commencement of the track census survey, and overnight activity is recorded on subsequent days.
- One-off snapshot surveys on other smaller islands to determine the presence/absence of nesting activity. The age of tracks recorded during a snapshot survey typically cannot be determined.

Marine turtle nesting activity will be identified by walking the length of the track census survey extent determined for each location (**Appendix B**). Marine turtle species and nesting activity (false crawl, attempt, or nest) will be determined using track and nest characteristics, including track width, shape and orientation of flipper marks, trail drag marks, displaced sand, and the depth of the nest pit and associated mound (Eckert et al. 1999). Any adult tracks that traverse the dunes and move inland will also be followed and documented.

Predator activity will be recorded and identified by tracks, scratchings and holes dug in the sand in the vicinity of a nest, which may have resulted in eggshells being scattered at the sand surface.

3.4.1.1 Data analysis

Since track census data is not available for the entire nesting season at all locations, and the number of survey days and sampling periods between years varied (see **Table 3**), a suitable approach will be used to explore trends in track and nesting numbers observed within discrete sampling periods as an indicator of relative abundance and distribution pre- and post-construction.

To identify sampling periods, the historic track census datasets were reviewed and peak periods for hawksbill and flatback nesting observations (green turtles were excluded due to their low nesting activity in the area), and periods with most consistent monitoring effort (in terms of years of sampled data) were identified. Two sampling periods were identified for each species as follows:

- Flatback turtles: 9–13-day sampling periods in December 2018 and 2021 on islands and December 2018 and 2022 on the mainland
- Hawksbill turtle: 12–14-day sampling periods in October and December 2021 on islands and October 2022 on the mainland.

Baseline survey effort falling within these sampling periods is summarised in **Table 9**. Data outside these periods will be excluded from future analyses.

Table 9. Baseline data summarised for flatback and hawksbill turtles at Long and Sholl Island, including the survey duration, total number of tracks, nesting success and the number of tracks and nests per day.

Location	Season	Survey days	Month	Species	Tracks (nesting success)	Tracks.d (nests.d)
Sholl	2018/19	13	Dec	Flatback	89 (44%)	6.8 (3)
	2021/22	14	Oct	Hawksbill	18 (44%)	1.3 (0.6)
		12	Dec	Hawksbill	9 (44%)	0.8 (0.3)
				Flatback	83 (41%)	6.9 (2.8)
Long	2018/19	13	Dec	Flatback	135 (30%)	10.4 (3.2)
	2021/22	13	Oct	Hawksbill	4 (0%)	0.3 (0)
		12	Dec	Flatback	64 (36%)	5.3 (1.9)
				Hawksbill	28 (50%)	2.3 (1.2)
Mardie Creek East	2018/19	13	Dec	Flatback	2 (0%)	0.2 (0)
	2022/23	14	Oct	Hawksbill	8 (38%)	0.6 (0.2)
		14	Dec	Flatback	8 (38%)	0.6 (0.2)
Mardie Creek West	2018/19	13	Dec	Flatback	2 (0%)	0.2 (0)
	2022/23	14	Oct	Hawksbill	0 (0%)	0 (0%)
		14	Dec	Flatback	0 (0%)	0 (0%)

Abundance

Descriptive statistics describing total number of tracks, number of nests, the number of tracks/nests per day, abundance (mean ± standard deviation, range and sample size) will be generated for each species and each location across all field surveys. The number of tracks recorded during the line-in day will also be documented as an indication of the amount of nesting activity prior to the start of the survey. Nesting success, calculated as the number of successful nesting events as a proportion of the total number of overnight tracks, will also be determined.

Cumulative monitoring results will be annually compared with the baseline dataset **(Table 9**). A suitable approach will be used to explore trends in track and nesting numbers observed within discrete sampling periods as an indicator of relative abundance pre- and post-construction (e.g., Generalised Additive Model approach or other suitable methods, depending on the dataset collected post-construction). The mainland will be excluded from any analysis due to the low activity, hence small dataset recorded during baseline surveys. There is therefore not enough data to detect possible changes in the abundance and distribution at this site, but it will be monitored due to its immediate proximity to the Project and will be discussed qualitatively.

Nesting habitat use

Track census data from the identified sampling periods at Long and Sholl Islands were combined to provide a complete dataset of nesting activity prior to project construction. This baseline dataset will be used to detect possible changes in the distribution (i.e., nesting behaviour) of adult turtles that may be attributed to the Project (as per MS1175 Condition 10-4 (5)).

To define survey areas from these datasets for the proposed analysis, all turtle tracks recorded during the identified sampling periods were plotted, and locations were used to define areas for track density calculations. Nesting activity on sand spits were excluded when defining areas due to their dynamic nature, and their variation in shape and size each year (black dashed line, **Figure 7**). As such, sections east and west of the sand spit were separated for this analysis (Sholl East and Sholl West). Removing the sand spit assumed that the overall area available for nesting in construction and operation will still include the same area that was available for baseline.

Track density within a 20 m radius will be calculated for all species combined using the heatmap tool in QGIS 3.6 (**Figure 7**). The heatmap will be generated using a Kernel Density Estimation and a quartic interpolation function with a 20 m search radius. A nearest neighbour spatial analysis will be used to test the amount of randomness in the spatial patterns of turtle tracks to show if there is a change in the usage of nesting beaches. The purpose of this analysis will be to determine how the spatial pattern of nesting activity has changed since baseline and to determine if that change is statistically significant. This analysis involves the measurement of the distance between each track and the next nearest sighting. It then averages all these nearest neighbour distances. If the average distance is less than the average for a hypothetical random distribution, the distribution of the sightings is considered clustered. If the average distance is greater than a hypothetical random distribution, the sightings are considered dispersed. The nearest neighbour index is calculated as the actual mean distance divided by the expected mean distance (with expected mean distance being based on a hypothetical random distribution with the same number of sightings covering the same total area).

During baseline, the nearest neighbour analysis showed that the pattern of nesting activity was dispersed across surveyed habitat at Sholl west whereas the pattern of nesting activity at Sholl East and Long Island was significantly clustered towards the southern end of each beach at both locations (**Figure 7**).

Figure 7. Track density of all species on Long and Sholl Islands within the survey area in 2018/19 and 2021/22.

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Coordinate System: GDA 2020 MGA Zone 50

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3.4.2 Nesting Habitat Health Assessment

*This work scope satisfies requirements of MS1175 condition 10-4 (3) (c) (**Table 1**)*

This work scope determines the proportion of turtle hatchlings emerging from nests at the end of a complete and undisturbed incubation period and is used to assess how productive the beach is in terms of turtle nesting. Nests will be marked in the earlier surveys (FS1 and FS2) and excavated in the last survey (FS3), after the nests have hatched out. In particular, the aim of nest marking, and excavation is to collect data on the health of the nesting habitat.

3.4.2.1 Nest Marking

Nests will be marked in FS1 (October) and FS2 (December) on Sholl and Long islands, and if they are encountered on the mainland (Mardie Creek East and West). Where possible, nests selected for marking will consider the spring high tide level to avoid nests being lost to erosion from high tides and wind as found in previous surveys (Pendoley Environmental 2022).

Clutches will be located by carefully digging into fresh nests identified during the track census and locating the eggs at the top of the nest. A temperature logger tethered to a marking post will be placed amongst the eggs to record the temperature profile during incubation. This data is used in nest success analysis. Control temperature loggers will also be deployed in the sand at 500 mm depth during FS1 at routine monitoring locations to track natural changes in sand temperature during the incubation period of marked nests.

3.4.2.2 Nest Excavation

Marked clutches will be excavated by removing and sorting the contents of each egg chamber. Clutch contents will be sorted to determine the number of hatched, emerged and dead individuals, and partially, fully or undeveloped embryos.

In addition to marked clutches, opportunistic clutches will also be excavated. Recently emerged nests will be identified in the first three days of the field survey and excavated in the final three days of the field survey to allow sufficient time for the nest to finish hatching. The clutches will be excavated with caution to avoid disturbance to any remaining live hatchlings within the clutch or to developing embryos that may not have hatched. The contents of the egg chamber will be sorted as per the marked clutches.

3.4.2.3 Clutch Fate

The fate of marked clutches and opportunistic nests will be classified as one of four categories:

- Complete: If a clutch was not lost, inundated, disturbed, or predated – i.e., it had been left undisturbed for the entire incubation period.
- Lost: If a clutch could not be located by the field team. This could be due to excessive sand deposition, erosion, disturbance from predators or other nesting turtles, or displacement of nest marking equipment.
- Inundated: If the temperature profile of a clutch showed a sudden substantial drop below the control temperature.

- Disturbed or predated: If the temperature profile of a clutch showed a sudden substantial increase in temperature.

3.4.2.4 Data analysis

Hatch and emergence success

Hatch success will be calculated by dividing the number of hatched eggs by the total number of eggs in the clutch. Hatchling emergence success (the percentage of hatchlings successfully leaving the nest) will be calculated by subtracting the number of live and dead hatchlings encountered in the egg chamber from the number of hatched eggs, and then dividing by the total number of eggs in the clutch.

Annual survey results will be compared against baseline hatch and emergence success rates. Statistics on incubation success results (hatch and emergence success) will explore trends in hatch and emergence success rates at each location and over monitoring years. Analyses may include conducting a Cochran-Armitage test to explore linear trends over time.

Incubation environment metrics

Temperature loggers deployed at control sites will be retrieved during Field Survey 3. The incubation period (IP) is the duration between the date a clutch was marked and the date the clutch hatched. The hatch date of each marked clutch classified as 'complete' will be determined by comparing the clutch temperature profile to the control temperature profile, whereby an independent drop in temperature in the clutch profile indicates that the nest has hatched and emerged. The IP will be summarised for each monitoring location.

Following identification of the hatch date for each clutch, descriptive statistics will be generated to describe the incubation environment of each clutch, including:

- mean clutch temperature for the incubation period,
- mean clutch temperature during the Thermosensitive Period (TSP), which represents the middle trimester of development and determines the sex ratio of a clutch (Yntema & Mrosovsky 1980, 1982; Hewavisenthi & Parmenter 2002), and
- the proportion of the incubation period where the mean daily temperature is greater than 33°C. This temperature is considered the lower bound of the upper thermal tolerance range (TTR) for flatback turtle incubation, above which embryo development is impaired (Ackerman 1997, Van Lohuizen et al. 2016).

Incubation metrics will be discussed on a year-by-year basis and in context with the incubation environment metrics determined for marked clutches in pre-construction surveys. Control logger temperatures will be used to calculate the mean daily temperature for the entire incubation period of marked clutches (October to December) each year as a tool to understand natural fluctuation in sand temperature, to compare to marked nests.

3.4.3 Hatchling Orientation

*This work scope satisfies requirements of conditions 10-1 (2), 10-4 (3) (d) and 10-4 (5) (**Table 1**)*

This work scope determines the spread of hatchling tracks emerging from nests based on the nest fan left in the sand. In particular, this scope aims to:

- collect data on hatchling orientation, and
- determine whether artificial light emissions are influencing the orientation of turtle hatchlings.

Hatchling orientation data will be collected from emerged nests on Sholl and Long Islands, and on the mainland when encountered during field surveys. Fan monitoring on islands in 2018/19 and 2021/22 found greater dispersion on island sand spits due to the most direct route to the ocean occurring in every direction, resulting in disorientation (see Section **2.2.3**) (Pendoley Environmental 2019, 2022). Consequently, future monitoring under this program will not include metrics from hatchling fans emerging on island spits as they are obscured by natural cues. Hatchling orientation metrics will be recorded for fans encountered in the 'hatchling orientation survey area', illustrated for each monitoring location in **Appendix B**. Orientation data may also be collected from other locations if time allows (**Table 8**).

Two metrics will be used to track fan spread and offset:

- **Spread angle**: this describes track dispersion from the emergence point, capturing the spread of all hatchling pathways toward the ocean. A larger value indicates greater dispersion or variation in ocean finding bearings and may indicate disruption to natural hatchling sea finding ability.
- **Offset angle:** this describes the degree of deflection of tracks from the most direct route to the ocean. A smaller value indicates a more direct route (i.e., less deviation from the most direct route) and a larger value demonstrates greater deviation from the most direct route, which may indicate disruption to natural hatchling sea finding ability.

A nest fan will be recorded if five or more hatchling tracks are sighted from a hatched clutch, indicated by a localise depression in the sand that marks the point of emergence (the nest cone, **Figure 8**). A sighting compass will be used to measure the bearing of the outermost tracks of the nest fan and the bearing of the most direct route to the ocean (**Figure 8**). Bearings will be measured from either the point where the track crosses the high tide line, or five metres from the clutch emergence point (whichever distance is shortest). Any tracks > 30° outside of the main fan defined by vectors A and B were considered outliers. The bearing of each outlier was recorded separately.

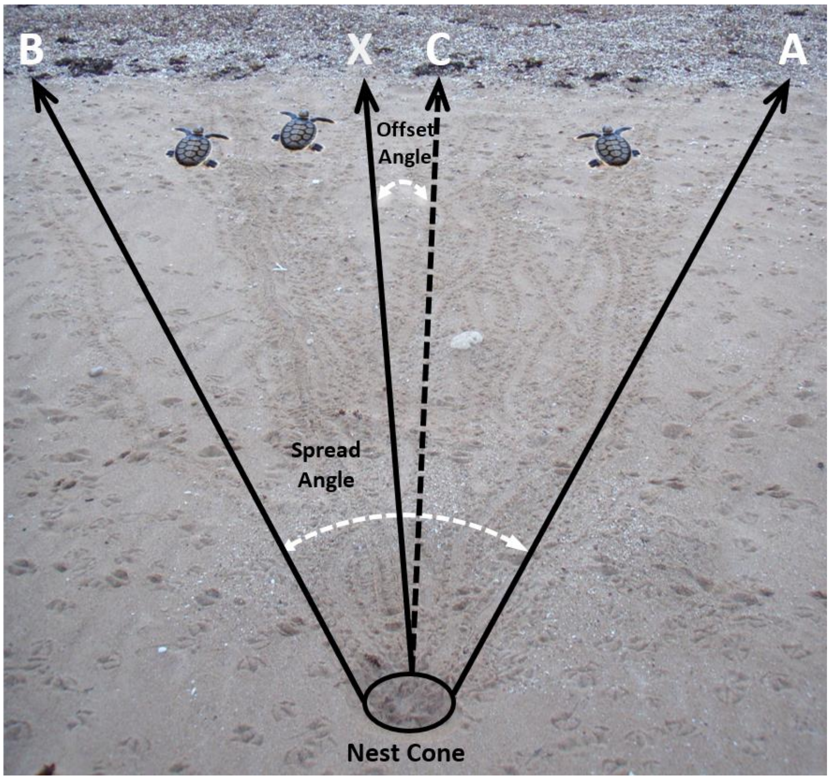

Figure 8: Hatchling orientation indices measured from the emergence point identified as the nest cone. A and B: the outermost bearings of the main fan, X: the bearing of the most direct route to the sea and C: offset angle.

3.4.3.1 Data analysis

An angle of spread was calculated as the angle between vectors A and B (Figure 8). The offset angle was determined by calculating the angle between the most direct line to the ocean (X) and the bearing bisecting the spread angle (vector C; Figure 8). For sites without adequate baseline data (e.g. the mainland where only n = 3 fans were obtained), hatchlings will be categorised as displaying no, moderate, or severe disorientation or misorientation depending on the size of the spread and offset angle. If hatchlings are categorised as displaying severe disorientation, then further investigations will be conducted into the cause. If it is found to be Project-attributable, then mitigation actions will be undertaken (see **Section 4**).

For Long and Sholl Islands, there was adequate data to establish benchmark metrics, therefore hatchling orientation data from 2018/19 and 2021/22 was combined to produce a baseline dataset to establish the natural range of orientation behaviours (**Table 10**). As these surveys found natural misorientation and disorientation of hatchlings on sand spits, these areas were omitted when calculating the baseline metrics (**Figure 9**). A circular regression model (Cremers et al. 2018) or other suitable analysis will be used to identify any significant differences between years for these two sites (when all seasons were combined). The circular regression model is recommended since orientation is circular in nature; for example, 0° and 360° represent the same direction, whereas on a linear scale they are very different quantities. Model estimates are obtained with a Bayesian approach and, therefore, there is not a single p-value for significance. Instead, the 'posterior estimate of the circular mean' and 95 % HPD (highest posterior density) intervals are interpreted to infer statistical significance. Alternative analyses may also be explored to identify significant differences between beaches (e.g. setting exceedance values of spread and offset that are considered statistically significant from baseline when they exceed the baseline mean + 2*StDev).

Table 10: Hatchling orientation data from survey areas on Sholl and Long Islands and for both locations combined.

Spread	***n***	**Benchmark Mean**	**StDev**
Sholl (east)	22	60.7	18
Sholl (west)	8	45.9	8.9
Long	37	52.7	16.7
All sites	**67**	**54.5**	**17.0**
Offset	***n***	**Benchmark Mean**	**StDev**
Sholl (east)	22	8.8	6.2
Sholl (west)	8	4.9	5.5
Long	37	8.7	6.8
All sites	**67**	**8.3**	**6.5**

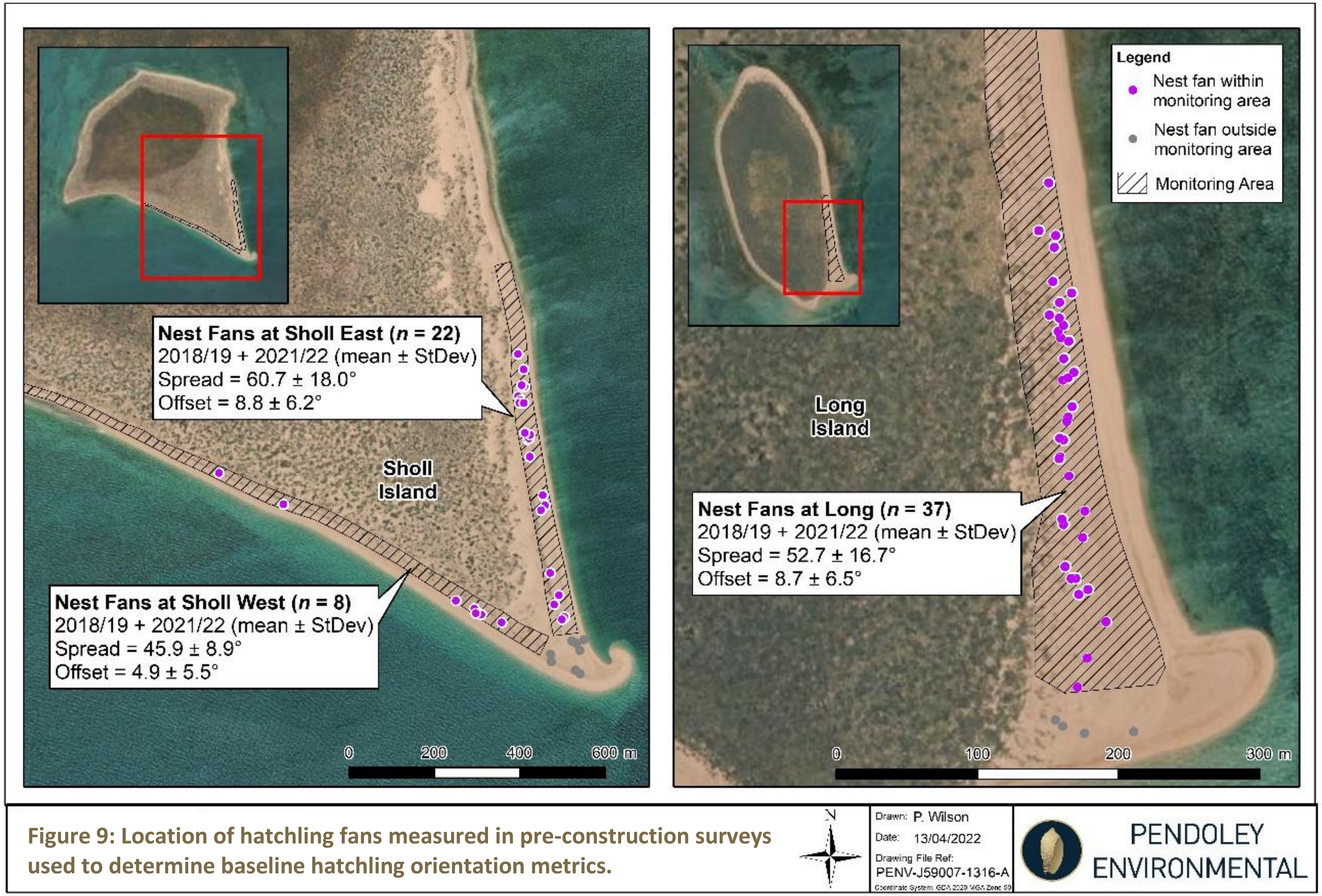

Figure 9: Location of hatchling fans measured in pre-construction surveys used to determine baseline hatchling orientation metrics.

3.4.4 Artificial Light Monitoring

*This work scope satisfies requirements of conditions 10-4 (3) (e) (**Table 1**)*

MS1175 Condition 9-1 requires an Illumination Plan to be developed in accordance with Western Australian and Commonwealth guidelines. In addition, as per Condition 10-1(2) and Condition 10-4(3) artificial light monitoring will be undertaken on islands and mainland beaches, where practicable. This scope of work aims to collect measurements on the intensity and extent of light sources visible from nesting beaches. Light monitoring equipment that is appropriate for capturing calibrated all sky imagery should be used (examples detailed in Appendix C of the National Light Pollution Guidelines for Wildlife (Department of Environment and Energy 2020).

Monitoring locations will be located within the defined hatchling fan monitoring zones on Long and Sholl Island, and on the mainland (see **Section 3.4, Appendix B**) and will be carried out during FS2 and FS3. Equipment will be deployed above the spring high tide line under new moon conditions.

3.4.4.1 Data analysis

Artificial light data (2021/22: offshore islands, 2022/23: mainland) will form a baseline dataset to be compared to light monitoring data gathered through the MTMP. Previous surveys used Sky42 cameras to identify and measure light sources. Images were batch processed using specialised software (Sky Quality Camera, Euromix Pty Ltd) following the identification and removal of poor-quality images (i.e., those impacted by moonlight, twilight or wind-blown sand). Processing involved converting each image to an isophote (light level) contour map and calculating the mean whole-of-sky brightness value (Vmag/arcsec^2) for all pixels in the map, zenith (60 – 90° field of view directly overhead), and horizon (0 – 30°). A single isophote map was then selected for each monitoring location to represent the median sky brightness with the least amount of influence from cloud and converted to equirectangular panoramas. The units of visual magnitudes per arcsecond squared are on an inverse logarithmic scale (higher values correspond to lower levels of light) (**Table 11**).

Sources of artificial light will be identified using Google Earth and Visible Infrared Imaging Radiometer Suite (VIIRS) light pollution data (www.lightpollutionmap.info). Suitable light monitoring equipment will be used to measure artificial light at night and provide outputs in a quantitative format that allows identification of new light sources, their magnitude and bearing. This data will be integrated with hatchling orientation data to qualitatively describe orientation in relation to visible light sources.

Table 11: Qualitative description of Sky42 Whole-of-sky (0 – 90°) Vmag/arcsec^2. Use as a guide only.

Whole-of-sky brightness (0 - 90°) (Vmag/arcsec2)	Description
21.5 – 22.0	Ideal natural dark night sky
21.0 – 21.5	Rural night sky
20.0 – 21.0	Semi-rural night sky
19.0 – 20.0	Suburban night sky
18.0 – 19.0	Urban night sky
< 18.0	Urban/Industrial night sky

3.5 Monitoring Limitations

Access to the islands and mainland beaches in the vicinity of the Project is constrained by several factors, including:

- The mainland beaches on the western side of Mardie Creek cannot be accessed by land due to an absence of serviceable vehicle tracks or roads. The location is outside the MS1175 approved Development Envelope, hence installing access is unlikely and not recommended.
- Approaching the mainland from the sea is restricted by the highly turbid water over extensive shallow rocky intertidal/subtidal zone which limits boat access to a few hours around high tide and prevailing westerly winds in excess of 10 knots, which makes the approach dangerous.
- Boat access to some of the islands is restricted on low tides and can be complicated in strong prevailing winds.
- Helicopter access to the islands must be approved by DBCA and carried out under a Regulation 4 Lawful Authority Notice to conduct Activity on CALM Land.
- Artificial Light at Night monitoring should only be conducted on or near to the new moon to avoid the confounding influence of moonlight on measurements.

Consideration should be given to tidal and moon phases, prevailing winds and site access when planning each field survey to best achieve the aims of this program.

4 Adverse Impact Response

In the event that the ongoing monitoring program detect a statistically significant change in the percentage range and usage of nesting sites or in hatchling orientation metrics, compared to the baseline data, an investigation into the cause of this change will be implemented by a subject matter expert (SME) retained by BCI. It is noted that MS1175 10-4 (5) only relates to detecting a decrease in percentage range and usage of data collected in the 2018/19 surveys (**Appendix A**). This dataset was supplemented with the additional data collected in 2021/22 and 2022/23. Combined, these three surveys form a more robust baseline dataset that can be compared to data collected through the MTMP as described in the sections above. The investigation will use published information and any available data to determine if the detectable adverse impact is due to;

- Natural interannual fluctuations in marine turtle nesting effort,
- Natural influences such as cyclones, heavy rain events inundating beaches, El Nino/La Nina impacts on sea temperatures and associated foraging habitat or other adverse weather events (global warming and sea level rise),
- Other operators in the region, i.e., contributing artificial light to the night-time environment, or
- Project lighting, including light sources such as the onshore plant and operations, offloading jetty and conveyors or transhipment vessels.

Should the impact be found to be Project attributable, the cause of the impact will be identified and mitigated and, if appropriate, the Illumination Plan will be revised to include the mitigation and management actions (see Section 5). Measures to reduce light to offshore islands should an adverse impact be detected include:

- Conducting an audit of the project lighting to identify individual lights that are directly visible or poorly shielded,
- Modifying light fixtures to include additional shielding and/or reorientation of light fixtures,
- Reducing the colour temperature or intensity of light sources,
- Eliminating lights that are surplus to operational needs,
- Investigating novel and emerging lighting technologies.

Should adult turtles be clearly misoriented/lost inland or trapped in the salt ponds, BCI will consult with marine turtle SMEs to plan the most appropriate response. In the first instance, individuals will be carried back to the nearest beach and the event reported to the Department of Biodiversity, Conservation and Attractions (DBCA) office in Karratha within 5 days. The response to any turtles trapped in a salt pond will be assessed on a case-by-case basis and a recovery plan discussed in conjunction with marine turtle SMEs and DBCA.

All fauna observations will be included in the BCI fauna sighting register which documents the date, time, coordinates, and activity of fauna on the Project site.

A summary of mitigation commitments is provided in Table 12.

5 ADDITIONAL COMMITMENTS

As per MS1175 Condition 10-4 (4), the MTMP will be implemented between October and February each year commencing October 2023/2024.

The annual monitoring results and cumulative monitoring results will be compared against the baseline assessment results as outlined in Pendoley Environmental 2019 (2018/2019 green and flatback nesting season results). In addition, there is scope to widen the comparison to include baseline data collected in Pendoley Environmental 2022 (2021/2022 hawksbill, green and flatback nesting season results) and Pendoley Environmental 2023 (2022/23 hawksbill and flatback nesting season on the mainland). The program will continue until the monitoring results demonstrate no adverse impact to marine turtle behaviour on offshore islands as a result of Project-attributable light (MS1175 Condition 10-1(2) and 10-6).

With reference to MS1175 Condition 10-4(5), should adverse impacts to marine turtle behaviour as a result of light be detected on turtles nesting, including a decrease in percentage range and usage of nesting sites from the 2018/19, 2021/22 and 2022/23 baseline study results, BCI will work with lighting designers and qualified turtle biologists/ecologists to implement mitigation options as outlined in the approved Illumination Plan.

With reference to MS1175 Conditions 9-1 to 9-5, Illumination and Lighting, the approved Illumination Plan will be revised, amended, and submitted for CEO approval following the implementation of any mitigation activities implemented under Condition 10-4(5).

Table 12 summarises the mitigation measures to reduce potential impacts from the Project, including light impacts, to significant nesting habitat (offshore islands).

Table 12. Summary of commitments to avoid and/or mitigate impacts to marine turtle nesting habitat.

Scenario	Mitigation	MS1175 condition
*Phased lighting designing and installation	Develop and implement an approved Illumination Plan prior to lighting for construction or operations.	9-1
Avoid direct impacts to offshore islands.	N/A - offshore islands are outside the Project Development Envelope; hence these sandy beach habitats are excluded from direct impacts by the Project.	10-3(3)
Minimise impacts to mainland sandy beach habitat (not deemed significant turtle nesting habitat)	**Eliminate** • Current schedule is for works that are within sandy beach habitat to occur in June 2023, well outside the peak marine turtle nesting and hatching season (October to March). • Restricting access to marine turtle nesting beach to authorised personnel for activities that are necessary to the Project (jetty construction, environmental surveys) and authorised by regulatory conditions of approval. **Engineer** • Jetty design was refined to increase the spanning distance between piles from 24 m to 27 m, resulting in only a single pair of piles directly	10-3(3)

Scenario	Mitigation	MS1175 condition
	impacting the 0.12 ha marine turtle nesting habitat. • Jetty construction method uses a top-mounted traveller to install piles. Therefore, direct disturbance within 0.12 ha marine turtle nesting habitat is limited to only the footprint of the piles. No machines will enter the beach habitat. **Administrate** • Minimise potential environmental impacts through implementation of the Mardie Ground Disturbance Permit (GDP) Procedure. • Ensure employees and contractors are aware of turtle nesting habitat through the Mardie Environmental Induction. • implement controls signage in proximity to the turtle nesting habitat and educational posters throughout the common areas of Project buildings.	
statistically significant decrease in percentage range and usage of nesting sites	• Consult with lighting designers and qualified turtle biologists/ecologists • Review and revise Illumination Plan	9-5
statistically significant change in the hatchling orientation metrics	Reduce light to offshore islands, which could include: • Audit project lighting to identify individual lights that are directly visible or poorly shielded, • Modify light fixtures to include additional shielding and/or reorientation of light fixtures, • Reduce the colour temperature or intensity of light sources, • Eliminate lights that are surplus to operational needs, • Investigate novel and emerging lighting technologies.	10-4(5)
Turtles misoriented/lost inland or trapped in Ponds	Consult with marine turtle subject matter experts (SMEs) to plan the most appropriate response. In the first instance, individuals will be carried back to the nearest beach and the event reported to DBCA office in Karratha within 5 days. Fauna observations are recorded in BCI fauna sighting register which documents the date, time, coordinates, and activity of fauna on the Project site.	N/A – mainland beaches not significant nesting habitat.

6 *** This relates to the separate but related Illumination Plan required by MS1175 condition 9 .**

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Appendix A: Approval Conditions

Ministerial Condition No. 1175

Marine Fauna

10-1 *The proponent shall implement the proposal to meet the following environmental outcomes:*

1) *clearing in the fauna habitat type identified as low-quality turtle nesting habitat (sandy beach habitat) in the Mardie project – Environmental Review Document (June 2020) is limited to a width of 50 metres, parallel to the high water mark;*

2) *no adverse impact to **marine turtle** behaviour on offshore islands as a result of project attributable light;*

3) *no entrainment or entrapment of **marine turtles** and fauna within seawater intake pipes (primary, desalination, and diffuser intake), which will be fitted using a four (4) side screen with no larger than 5 millimetres mesh width. Seawater intake on these pipes must not exceed 0.15 metres per second.*

10-2 *In order to demonstrate that direct impacts to significant **marine turtle** habitat will be minimised as far as practicable, the proponent shall conduct a pre-construction **marine turtle** survey within habitat identified as sandy beach habitat in the Mardie project – Environmental Review Document (June 2020).*

10-3 *The proponent shall avoid any construction activity within habitat identified as sandy beach habitat in the Mardie project – Environmental Review Document (June 2020), until the CEO has confirmed by notice in writing that:*

(1) *the surveys required by condition 10-2 have been conducted in accordance with best practice, by a qualified fauna (**marine turtle**) specialist and completed during the entire breeding and hatchling season of marine turtles;*

(2) *outcomes of the surveys required by condition 10-2 have been provided to DAWE, DBCA, DWER; and*

(3) *where significant **turtle** nesting habitat has been identified by surveys required by condition 10-2, mitigation measures to reduce potential impacts to the beach area as far as practicable have been identified and the proponent has committed to implementing the identified mitigation measures.*

10-4 *Prior to the commencement of operations the proponent shall submit to the CEO a Marine Turtle Monitoring Program. This plan shall:*

1) *when implemented, substantiate that the outcome required by condition 10-1(2) is being met;*

2) *when implemented, determine whether artificial light emissions are influencing nesting and mis-orientation or disorientation of **turtles** on the offshore islands (including but not limited to Long and Sholl Islands), and any areas determined to be significant **turtle** nesting habitat by surveys required by condition 10-3;*

3) *specify the details of the methodology of monitoring of the nesting turtle population in the proposal area and offshore islands, including nesting adults and hatchlings, during the species-specific reproductive period, which is to include (but not be limited to):*

*a) identification of the species of **turtles** nesting on the beaches;*

b) identification of the abundance and the distribution of adult tracks on the nesting beaches;

c) collection of data on the health of the nesting habitat;

d) collection of data on hatchling orientation; and

e) measurements on the intensity and extent of light sources visible from nesting beaches.

4) include a commitment to annually compare cumulative results against the baseline assessment (Pendoley Environmental 2019, Mardie Salt Project Marine Turtle Monitoring Program 2018/2019. Rev 0, Report No. RP-59001);

5) include measures to reduce light to offshore islands to be implemented in the event that adverse impacts from the proposal are detected, including a decrease in percentage range and usage of nesting sites (from the baseline study (Pendoley Environmental 2019, Mardie Salt Project Marine Turtle Monitoring Program 2018/2019. Rev 0, Report No. RP-59001); and

6) provide criteria for when the Illumination Plan required by condition 9-1 will be revised in response to outcomes of the monitoring required by condition 10-6.

10-5 *Unless otherwise agreed by the CEO, the proponent shall not commence operations until the CEO has confirmed in writing that the Marine Turtle Monitoring Program addresses the requirements of condition 10-4.*

10-6 *The proponent shall continue to implement the Marine Turtle Monitoring Program until the CEO has confirmed by notice in writing, on advice from DBCA and DWER, that the outcome of condition 10-1(2) has been, and will continue to be met.*

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19. To minimise **impacts** to **marine turtles,** the approval holder must:

a. comply with condition 10 of the **WA Approval**.

b. not commence any marine **construction** within the **marine turtle nesting beach** unless the **Minister** has also been consulted the mitigation measure required under condition 10-3 of the **WA Approval** and have approved these measures in writing.

c. not commence any marine **construction** within the **marine turtle nesting beach** unless the **Minister** has approved in writing the *Marine Turtle Monitoring Program* required under condition 10-4 of the **WA Approval**. The approval holder must implement the approved *Marine Turtle Monitoring Program* for the **life of the project** or until the **Minister** has confirmed in writing that the *Marine Turtle Monitoring Program* is no longer required. **Evidence** that condition 10-4(2) of the **WA Approval** is met must be developed with, and reviewed by, a **suitably qualified expert** in marine turtle ecology and be provided to the **Minister** for review.

d. Contact the **Department** if the outcomes of the **monitoring data** from the *Marine Turtle Monitoring Program*, identifies further **impacts** to **marine turtles** arising from the action, exceed, or are predicted to exceed, from the baseline data within the *Pendoley Environmental 2019, Mardie Salt Project Marine Turtle Monitoring Program 2018/2019. Rev 0, Report No. RP-59001*, then the approval holder must, within 3 months of identifying any such exceedance, or predicted exceedance, submit either a:

   i. revised and additional avoidance and mitigation measure to reduce **impacts** to **marine turtles**; or

   ii. an Offset Strategy specifying how the **impact** will be offset in accordance with the **Environmental Offsets Policy**.

e. If the revised and additional avoidance and mitigation measures or Offset Strategy has not been approved by the **Minister** in writing within 5 months of the exceedance event, and the **Minister** notifies the approval holder that the avoidance and mitigation measures or Offset Strategy is not suitable for approval, the **Minister** may, at least two months after so notifying the approval holder, approve a version of the avoidance mitigation measures or Offset Strategy revised by the **Department**. The approval holder must implement the approved avoidance and mitigation measures or Offset Strategy for the remainder of the **life of the project.**

Appendix B: Nesting Data and Survey Extents for Monitoring Locations

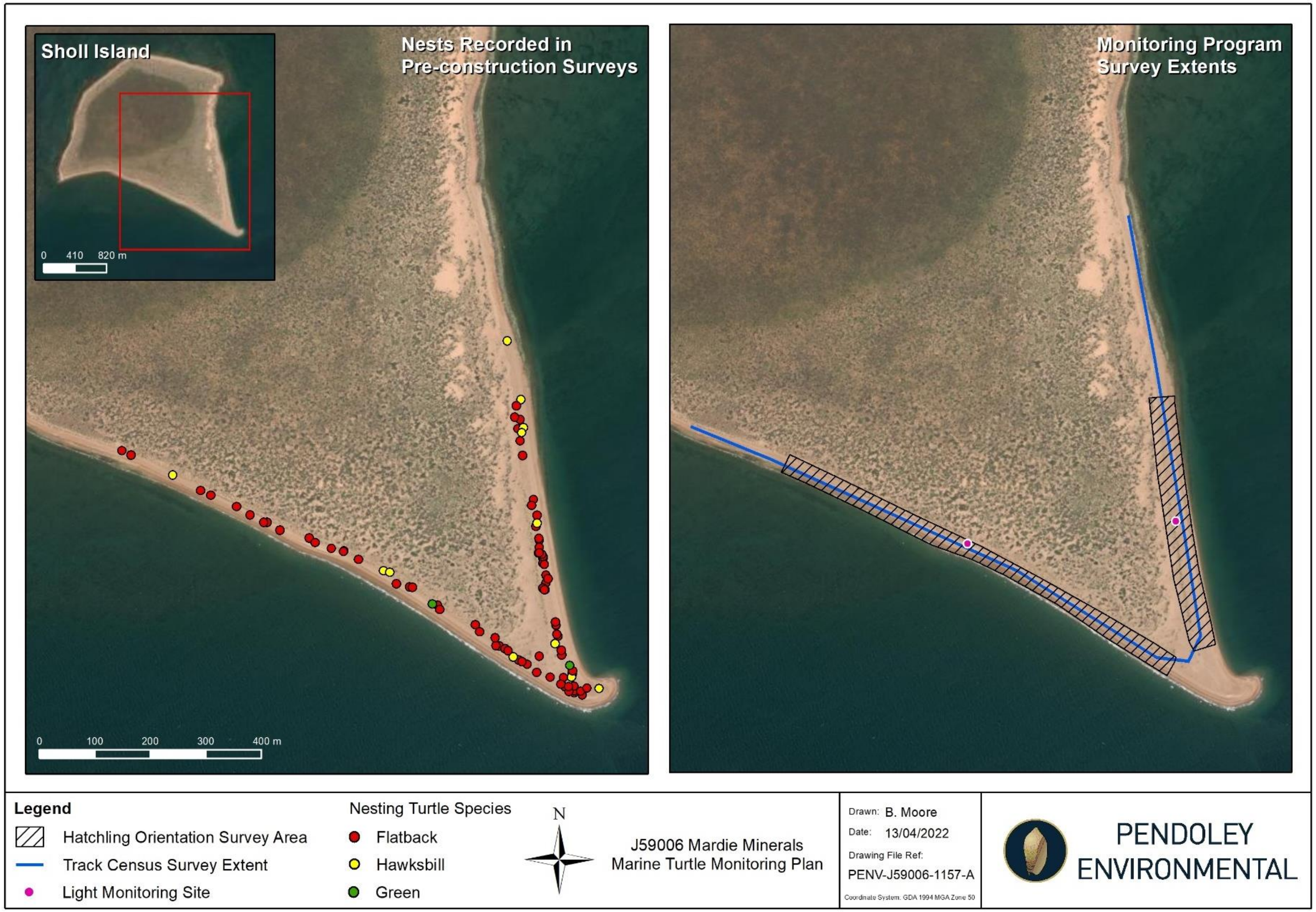

Figure B1: Marine turtle nests recorded on Sholl Island during pre-construction surveys (left) and routine monitoring survey extents defined for work scopes under the Marine Turtle Monitoring Program (right).

Figure B2: Marine turtle nests recorded on Round Island during pre-construction surveys (left) and opportunistic survey extents defined for work scopes under the Marine Turtle Monitoring Program (right).

Figure B3: Marine turtle nests recorded on Long Island during pre-construction surveys (left) and routine monitoring survey extents defined for work scopes under the Marine Turtle Monitoring Program (right).

Figure B4: Marine turtle nests recorded on Middle Passage Island during pre-construction surveys (left) and opportunistic survey extents defined for work scopes under the Marine Turtle Monitoring Program (right).

Figure B5: Marine turtle nests recorded on Angle Island during pre-construction surveys (left) and opportunistic survey extents defined for work scopes under the Marine Turtle Monitoring Program (right).

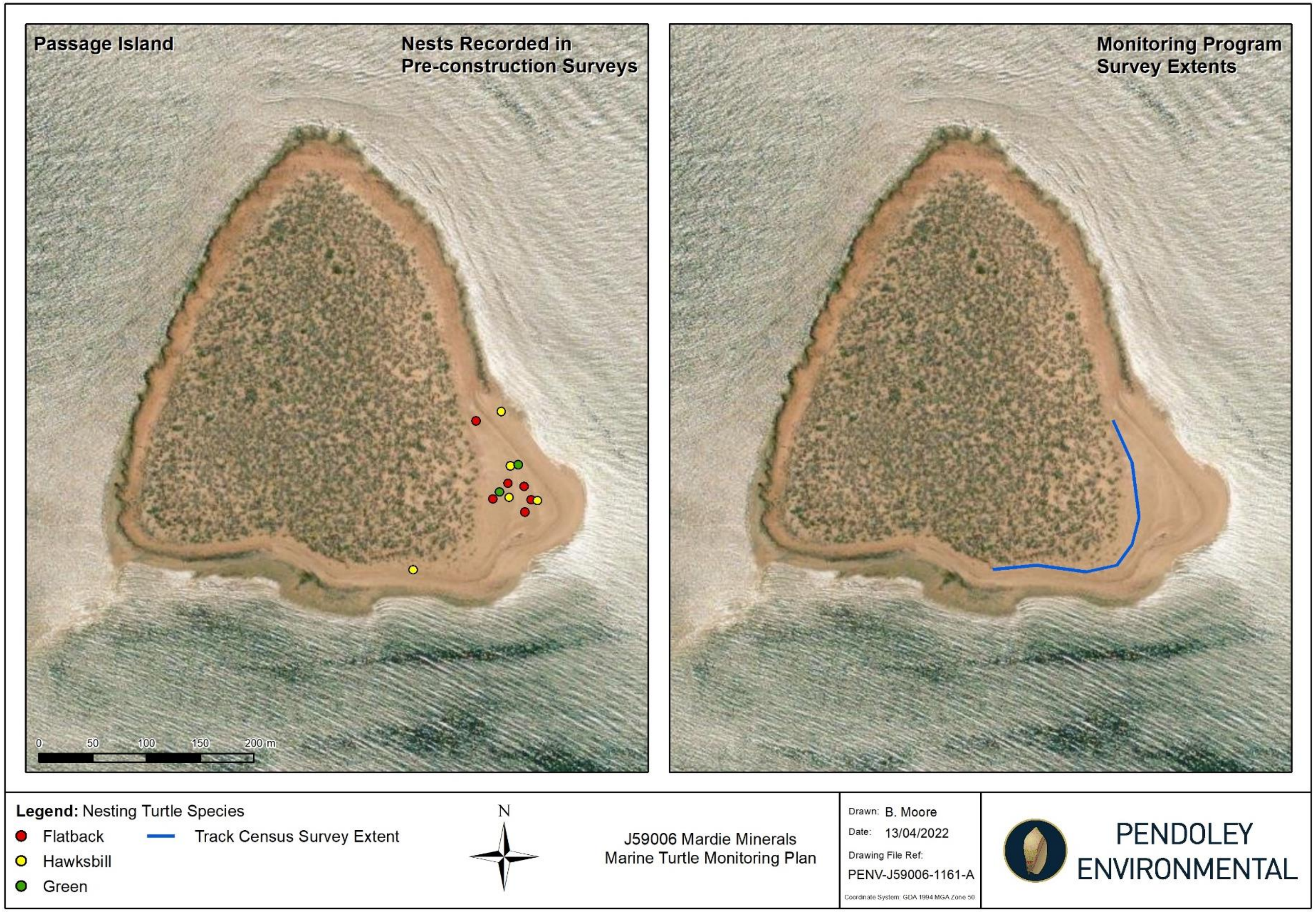

Figure B6: Marine turtle nests recorded on Passage Island during pre-construction surveys (left) and opportunistic survey extents defined for work scopes under the Marine Turtle Monitoring Program (right).

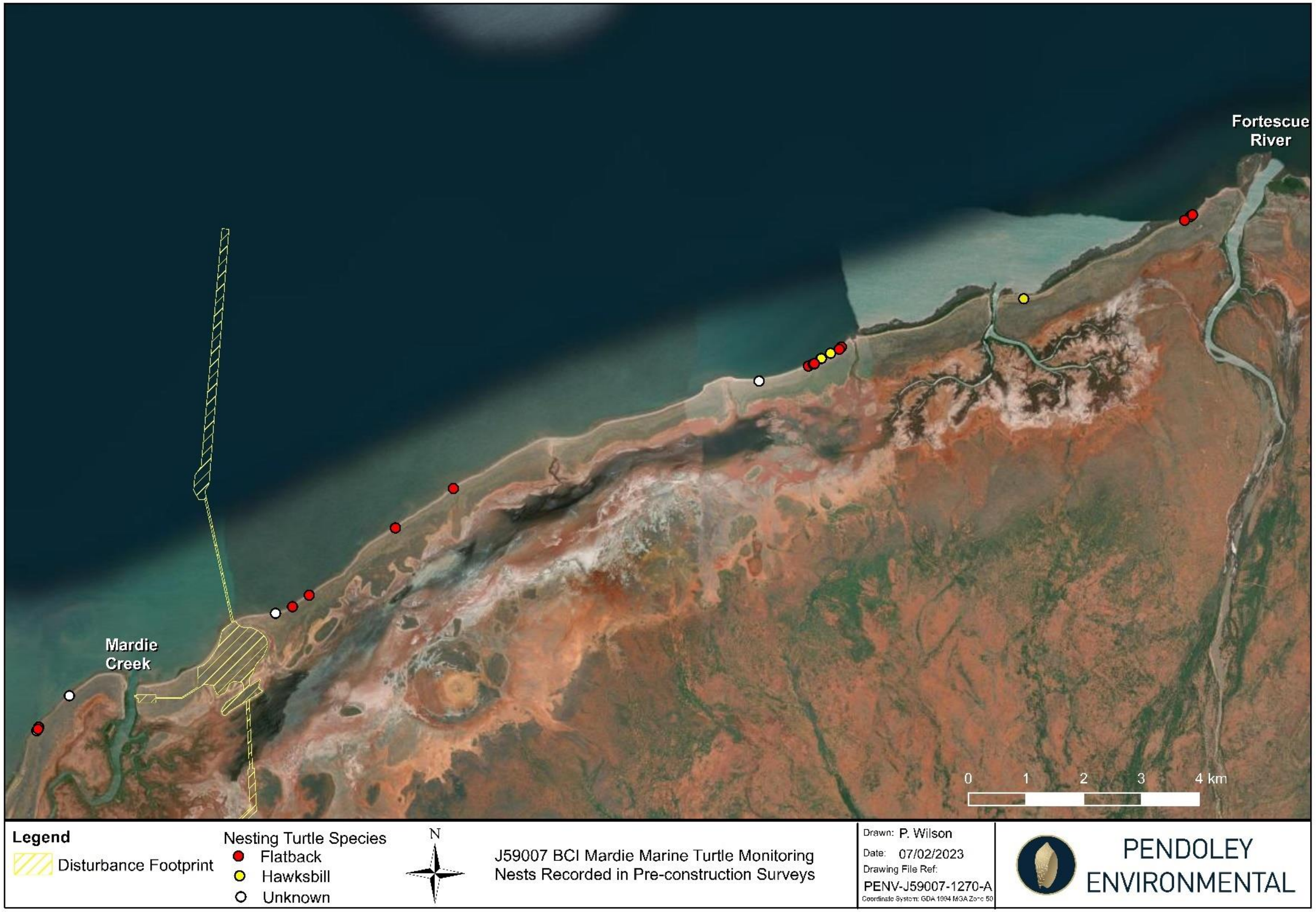

Figure B7: Marine turtle nests recorded on mainland beaches during pre-construction surveys.

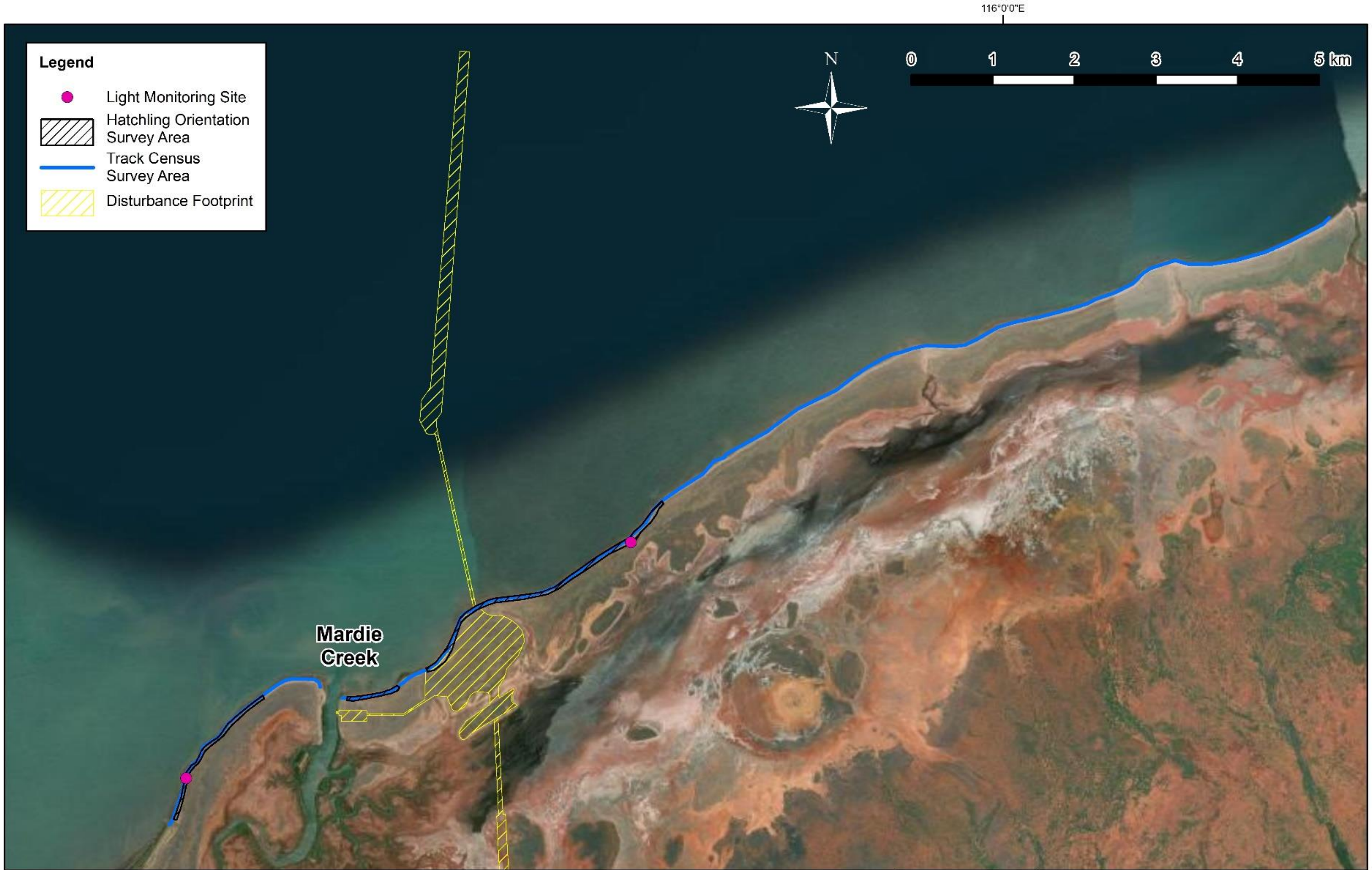

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Figure B8: Mainland survey extents defined for the Marine Turtle Monitoring Plan. Note that the track census survey area will be reduced if site access is by foot.

Drawn: B. Moore
Date: 13/09/2022
Drawing File Ref: PENV-J59007-1226-A
Coordinate System: GDA 2020 MGA Zone 50

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